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Physiological and Cognitive Mediators for the Association Between Self-reported Depressed Mood and Impaired Choice Stepping Reaction Time in Older People

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Background. The aim of the study was to use path analysis to test a theoretical model proposing that the relationship between self-reported depressed mood and choice stepping reaction time (CSRT) is mediated by psychoactive medication use, physiological performance, and cognitive ability.

Methods. A total of 280 retirement village residents, aged 62–95 years, undertook tests of CSRT, which required them to step onto one of four panels that were illuminated in a random order. Depressed mood was assessed using the 30-item Geriatric Depression Scale (GDS). The participants were also tested on physiological and cognitive performance, including quadriceps strength, balance, complex attention (Trail Making Test [TMT] B), simple reaction time, reported level of exercise, and use of psychoactive medications.

Results. A total of 51 participants (18%) showed mild to severe depression. Those with higher GDS scores had significantly increased CSRT and worse performance on all physiological and cognitive parameters. CSRT was also significantly associated with all other measures. The final path analysis model revealed an association between self-reported depression and CSRT that was mediated by two paths, one through quadriceps strength and the other through TMT B with both mediating variables then influencing CSRT via simple reaction time and balance.

Conclusions. The findings suggest that self-reported depressed mood is related to slowed performance on a CSRT task and that this relationship is explained by underlying physiological and cognitive impairments.

Key Words: Depression—Accidental falls—Exercise—Psychoactive medications—Balance.

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DEPRESSION and falls are both common in older people. Approximately 15% of community-living people aged more than 65 years report significant depressive symptomatology (1–5), with a higher rate (32% in one study) (5) reported for residents of aged care facilities. Prevalence estimates of falls are also high, with approximately 35% of older people living in the community and 50% of people living in residential aged care falling each year (6–8).

Depression and falls have both been linked with adverse outcomes, including increased risk of mortality; disability; and impaired functioning, including loss of confidence and restriction of activity (9–13). Depression has been shown to be a consistent risk factor for falls in prospective studies, but the underlying mechanisms for this are not yet fully understood (8,14). A number of factors that are correlated with depression have also been shown to be related to an increased risk of falling, including cognitive function; reaction time; balance; strength; and use of psychoactive medications, including antidepressants, antipsychotics, and benzodiazepines (15–17). Self-reported depressed mood has been shown to place people at an increased risk of physical decline in the absence of preexisting physical disability and is associated with impaired complex attention, working memory impairment, and executive dysfunction (18–21). It can be expected that a number of these factors may mediate the relationship between depression and falls.

In previous studies, we have found that a functional test of stepping performance—choice stepping reaction time (CSRT), is a good predictor of falls (22,23). The CSRT test requires participants to step from either leg onto targets that

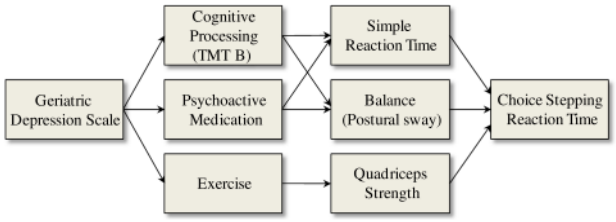

Figure 1. Hypothesized paths for the relation between Geriatric Depression Scale and choice stepping reaction time: a cognitive and a medication path, with complex attention (Trail Making Test [TMT] B) and psychoactive medication as mediators for simple reaction time and balance, respectively, and a physiological path, with exercise as mediator for muscle strength.

are illuminated randomly, and thus, body weight and balance transfers are similar to the step responses required to avoid many falls, particularly those that result from late visual detection of hazards and unexpected changes in the gait path. The current study aims to investigate why depressed people are more likely to fall by exploring, with path analysis, the relationship between self-reported depressed symptoms and CSRT (22). As path analysis can distinguish between direct and indirect associations, it can confirm the extent to which the relationship between depression and CSRT is explained by physiological, cognitive, and health-related factors. As CSRT is a continuously scored measure, it has an advantage over using falls as the outcome measure in that there is greater scope for explaining variance in the path model.

For parsimony, we used only functional measures in the model building. This approach indirectly accounts for level of education and the presence of medical conditions and associated medication use as the impact of these variables should be manifest in one or more of the physiological and cognitive measures included in the model (17). It also overcomes the issue of accounting for relative severity of specific medical diagnoses (eg, stroke, arthritis, cognitive impairment), which vary greatly among participants. We hypothesized that higher levels of depressive symptoms will be related to slowed stepping on the CSRT task through three distinct but related paths: a cognitive path, a medication path, and a physiological path (Figure 1).

Methods

Participants

A total of 280 participants (44 men and 236 women) aged 62–95 years (*M* 79.0, *SD* 6.5) comprised the study sample. The participants were residents of retirement villages in Sydney, Australia, and consisted of the control group of a randomized controlled trial of group exercise on falls risk factors (24). Participants were excluded from taking part if they had a standardized Mini-Mental State Examination (MMSE) score less than 20, had a medical condition that prevented them from taking part in the exercise program (as determined by nursing staff or a physician at pretest), or were attending exercise classes of equivalent intensity to the study intervention (25).

Assessments

Symptoms of depression were assessed using the 30-item Geriatric Depression Scale (GDS), a well-validated measure of mood specifically designed for use with older people (26,27). The GDS includes 30 yes or no self-report questions, with scores of 11–20 indicating mild to moderate depression and scores greater than 20 indicating severe depression (26,28). Participants also completed a part of the Incidental and Planned Activity Questionnaire, which provided detailed information on frequency and duration of average weekly exercise for a period of 3 months (24). Total time spent exercising was derived from multiplying frequency score and duration score to create a total duration of hours per week score. Activities qualifying as planned exercise included walking, activity classes, bowls, golf, tennis, swimming, dancing, jogging, and bicycling. In addition, all medications that participants were using were recorded directly from their containers. Medications of most interest were the psychoactive medications (sedatives/hypnotics, antidepressants, antipsychotics, and antianxiety agents).

For the CSRT measurements, participants stood on a nonslip black platform (0.8 × 0.8 m) that contained four rectangular panels (32 × 13 cm), one in front of each foot and one to the side of each foot (22). One panel per trial was illuminated in a random order. Participants were instructed to step on to the illuminated panel as quickly as possible, using the left foot only for the two left panels (front and side) and the right foot only for the two right panels. Each panel contained a pressure switch to determine the time of foot contact. After 4–8 practice trials, 20 trials were conducted with 5 trials per panel. CSRT was measured as the time period between panel illumination and the foot making contact with it. The average time of the 20 trials was used in the analysis.

Physiological performance was assessed using quantitative assessments of reaction time, lower limb strength, and postural sway (17). "Simple reaction time" was measured using a light as the stimulus and a finger press as the response. "Quadriceps strength" was measured for each leg as the maximal isometric extension force with a strain gage attached around the ankle while participants were seated with hip and knee angles of 90°. The best of three trials was recorded, and the average of these scores for both legs was calculated. "Postural sway" was measured using a sway meter that recorded displacements of the body at the level of the waist. Testing was performed with participants standing on a foam rubber mat (40 × 40 cm and 7.5-cm thick) with eyes open for a period of 30 seconds. The validity and reliability of these tests have been established in previous studies (17).

In addition to the physiological measures, complex attention was tested using the Trail Making Test (TMT) B, which requires participants to draw lines connecting a number of circles alternating between letters and numbers (eg, 1-A-2-B) (29). TMT B was chosen as the primary neuropsychological

Table 1. Prevalence of Major Medical Conditions, Medication Use, Participation in Physical Activity, and Mobility and ADL Limitations in the Total Study Population and for People With a GDS > 10 or ≤ 10. *p* Values Indicate Statistical Differences Between GDS Groups

Condition	Total (*n* = 280), *n* (%)	GDS > 10 (*n* = 50), *n* (%)	GDS ≤ 10 (*n* = 230), *n* (%)	*p* Value
Education ≤ 10 y	147 (52.7)	31 (62.0)	116 (50.7)	.145
MMSE < 24	59 (21.1)	20 (40.0)	39 (17.0)	<.001
BMI < 20	18 (0.07)	5 (49.0)	13 (0.06)	.273
Medical conditions (self-reported)				
Poor vision	53(18.9)	14 (28.0)	39 (17.0)	.071
Poor hearing	117 (41.8)	27 (54.0)	90 (39.1)	.053
Stroke	28 (10.0)	6 (12.0)	22 (9.6)	.603
Heart disease	82 (29.3)	23 (46.0)	59 (25.7)	.004
High blood pressure	142 (50.7)	25 (50.0)	117 (50.9)	.911
Low blood pressure	31 (11.1)	6 (12.0)	25 (10.9)	.817
Respiratory conditions	43 (15.4)	9 (18.0)	34 (14.8)	.567
Foot problems	78 (27.9)	13 (26.0)	65 (28.3)	.747
Arthritis	178 (63.6)	35 (70.0)	143 (62.2)	.297
Diabetes	25 (8.9)	7 (14.0)	18 (7.8)	.165
Medication use				
Four plus medications	135 (48.2)	32 (64.0)	103 (44.8)	.014
Antidepressants	24 (8.6)	8 (16.0)	16 (7.0)	.038
Psychoactive medications	88 (31.4)	27 (54.0)	61 (26.5)	<.001
Cardiovascular system medications	191 (68.2)	37 (74.0)	154 (67.0)	.332
Musculoskeletal system medications	48 (17.1)	6 (12.0)	42 (18.3)	.287
Exercise more than 3 h per week	118 (42.1)	13 (26.0)	105 (45.7)	.011
One or more falls in past year	97 (34.6)	21 (42.0)	76 (33.0)	.228
Mobility and ADL limitations				
Used a walking aid	82 (29.3)	21 (42.0)	61 (26.5)	.029
Difficulty shopping	69 (24.6)	23 (46.0)	46 (20.0)	<.001
Difficulty clothes washing and/or room cleaning	24 (8.6)	10 (20.0)	14 (6.1)	.001
Difficulty cooking	49 (17.5)	17 (34.0)	32 (13.9)	.001
Difficulty dressing	7 (2.5)	3 (6.0)	4 (1.7)	.080
Difficulty bathing and/or toileting	6 (2.1)	3 (6.0)	3 (1.3)	.038

Note: ADL = activities of daily living; BMI = body mass index; GDS = Geriatric Depression Scale; MMSE = Mini-Mental State Examination.

test as it requires a number of cognitive domains, including visual perception, visual scanning, fine motor coordination, psychomotor speed, as well as divided attention and mental flexibility. When a participant made an error, it was pointed out immediately and the participant was allowed to correct it. These corrections were included in the total time (29). Time taken to complete the test was measured, with less time indicating better performance.

Statistical Analyses

Statistical analyses were performed using SPSS (version 16.0) in conjunction with Analysis of Moment Structures Graphics (AMOS 7.0). Multivariate normality and linearity were evaluated by examining the normality, linearity, and homoscedasticity of the individual variables and residuals. After logarithmic transformations of CSRT, sway, simple reaction time, quadriceps strength, TMT B, and a square root transformation of the GDS and exercise variables assumptions regarding multivariate normality were met, and all parametric statistics were performed with the transformed data. Bivariate correlations between variables were calculated using Pearson's and point-serial correlation analyses, and differences in the means of the physiological, cognitive, and exercise variables between people with a GDS ≤ 10 and people with a GDS > 10 were assessed using independent samples *t* tests.

Path analysis in AMOS was then performed to examine the relationship between GDS and CSRT and to evaluate our hypotheses on the mediating role of the medication, physiological, and cognitive parameters. Path analysis is an optimal statistical technique for testing these hypotheses as it can evaluate a priori models, suggest causal sequences, identify mediators, and elucidate direct and indirect paths between the two end points.

We constructed a path model based on our hypothesis and on significant correlations. Goodness of fit of the models was examined by chi square, goodness-of-fit index (GFI), and root mean square error of approximation (RMSEA) (30). Chi square should not be significant as it investigates lack of fit, resulting from overidentifying restrictions placed on a model (30). GFI should be high (>0.90) as it assesses the extent to which the model provides a better fit compared with no model at all (30). RMSEA should be small (<0.08) as it estimates lack of fit in a model compared with a perfect model (31). Finally, standardized regression coefficients (rc), which are analogous to correlation coefficients, and explained variances were calculated.

Results

Table 1 shows the prevalence of major medical conditions, medication use, physical activity, and functional ability for the

Table 2. Mean Values, *SD*, and Test Results in the Total Study Population and for People With a GDS < 10 or ≥ 10. *p* Values Indicate Statistical Differences Between GDS Groups

	Overall (*n* = 280)	GDS > 10 (*n* = 50)	GDS ≤ 10 (*n* = 230)	
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*p* Value
CSRT (ms)	1,190.6 (220.9)	1,263.7 (223.9)	1,174.7 (217.4)	.009
Quadriceps strength (N)	221.2 (92.8)	199.8 (84.3)	225.9 (94.1)	.060
Simple reaction time (ms)	286.7 (61.9)	306.1 (87.5)	282.6 (54.2)	.028
Sway eyes open on foam (mm)	178.6 (120.9)	208.0 (125.8)	172.3 (119.1)	.035
TMT B (s)	70.9 (53.3)	84.3 (55.0)	68.0 (52.6)	.003
Exercise (h/wk)	3.1 (3.3)	2.7 (3.8)	3.2 (3.2)	.167

Notes: High scores in the tests of CSRT, simple reaction time, sway and TMT B, and a low score in the test of quadriceps strength indicate impaired performances. CSRT = choice stepping reaction time; GDS = Geriatric Depression Scale; TMT B = Trail Making Test.

people with a GDS ≤ or > 10. Participants with GDS scores > 10 had lower MMSE scores, a higher prevalence of heart disease, were taking more antidepressant, psychoactive and total number of medications, took part in less exercise, and had greater difficulty undertaking activities of daily living.

The mean CSRT in the total population was 1,191 (*SD* 221) milliseconds. Age was significantly correlated with GDS ($r = .27$, $p < .001$) and with CSRT ($r = .34$, $p < .001$). Gender did not influence GDS ($t(1,278) = 0.02$, $p = .98$) but did influence CSRT where men where significantly faster than women ($t(1,278) = 2.48$, $p = .016$). This gender difference disappeared after adjusting for quadriceps strength in an analysis of covariance procedure ($F(1,277) = 0.258$, $p = .61$). Thirty-seven people (13.2% of sample) used a walking aid during the CSRT so that they could safely undertake the test. Aid users (1,333 ± 145 milliseconds) were significantly slower than nonaid users (1,169 ± 223 milliseconds; $t(1,278) = 6.46$, $p < .001$).

Table 2 shows the mean values and standard deviations for the CSRT and the physiological, cognitive, and exercise measures for the people with a GDS ≤ or > 10. People with a GDS > 10 had significantly increased CSRT and poorer performance on all tests except quadriceps strength compared with people with lower scores. CSRT was also significantly lower for people who were taking one or more psychoactive medications ($t(1,278) = 2.25$, $p = .025$).

When coded as a continuous measure, GDS was significantly associated with all physiological and cognitive measures and with CSRT (Table 3). All assessment measures were also significantly associated with CSRT. Although use of psychoactive medications was significantly associated with GDS and CSRT, the latter coefficient was relatively low ($r^2 < .20$).

The initial path analysis model included all associations between GDS, CSRT, physiological, and cognitive variables with significance levels ≤ 0.001 (Table 3). As the use of psychoactive medication did not show any strong associations with measures other than GDS, this variable was not included in the model. This model showed that the direct (unexplained) effect of GDS on CSRT was very low (rc = .04) and no longer statistically significant, whereas the rc of the standardized indirect effect was .22. Furthermore, exercise appeared not to be an important mediator as the rc of the indirect effect of GDS on quadriceps strength over exercise was only .04, whereas the rc of the direct (unexplained) relation was −0.26.

All associations that were not statistically significant in our initial model were removed (Figure 2). Despite the significant chi square ($\chi^2 = 15.9$, $p = .014$), with a reasonable number of degrees of freedom (6), the goodness-of-fit indicators revealed that this final model had a good fit (GFI = 0.982 and RMSEA = 0.077). This model confirmed that the relation between GDS and CSRT was not direct but fully mediated by simple reaction time, balance, and quadriceps strength and followed both a cognitive path (complex attention) and a physiological path (quadriceps strength). Quadriceps strength

Table 3. Correlations Between GDS, the Test Measures, and CSRT

	GDS	Exercise	Psychoactive Medications	Simple Reaction Time	Quadriceps Strength	Balance (Sway)	Cognition (TMT B)
GDS	1.000	—	—	—	—	—	—
Exercise	**−0.229****	1.000	—	—	—	—	—
Psychoactive medications	0.257**	−0.112	1.000	—	—	—	—
Simple reaction time	0.172*	−0.176*	0.109	1.000	—	—	—
Quadriceps strength	**−0.255****	**0.238****	−0.091	**−0.325****	1.000	—	—
Balance (sway)	**0.263****	−0.111	0.020	**0.256****	**0.234****	1.000	—
Cognition (TMT B)	**0.325****	−0.149*	0.020	**0.366****	−0.193*	**0.355****	1.000
CSRT	**0.260****	**−0.232****	0.134*	**0.441****	**−0.491****	**0.403****	**0.325****

Notes: Low scores in quadriceps strength and high scores in all other variables indicate impaired performance. Significant correlations are indicated: *$p < .05$, **$p \leq .001$. Correlations in bold were included in the initial path analysis model. CSRT = choice stepping reaction time; GDS = Geriatric Depression Scale; TMT B = Trail Making Test.

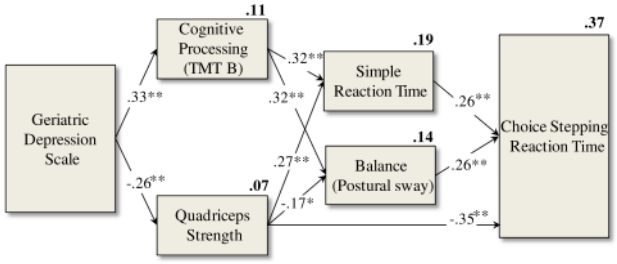

Figure 2. The final path analysis model and output. Direct effects of standardized regression coefficients between variables are shown on each arrow; significant values are indicated by $*p < .002$. and $**p < .001$. Explained variance is in bold above each variable.

was not only directly related to CSRT (rc = −.35) but also indirectly via simple reaction time and balance (rc = −.10). The mediators—simple reaction time and balance—were not directly related to GDS but indirectly via complex attention (indirect regression weights of rc = .17 and 0.13 for simple reaction time and balance, respectively). Finally, the results showed that 37% of the variance of CSRT was explained by the variables in this model.

Discussion

The path analysis of this study supports our hypothesis that the association between depressive symptoms and CSRT is not direct but mediated by two distinct paths: cognitive and physiological. First, participants with a higher level of self-reported depressed mood were more likely to score poorly on complex attention, an aspect of executive functioning (TMT B), which showed its effect on CSRT indirectly through slower simple reaction time and poorer balance. These findings are in keeping with previous research that has shown that depressive symptoms in older people are related to poorer information processing capacity and slowed reaction time, and people with mild cognitive impairment are more likely to have impaired postural stability and balance (18,20,21,32). Second, higher levels of depressive symptoms were related to slower CSRT through a physiological path. This relationship was mediated by quadriceps strength, which was both directly related to slower CSRT and indirectly through simple reaction time and balance. Quadriceps strength can be conceptualized as a measure of general vitality, and various measures of strength have been used in quantitative batteries of frailty (33,34). It was hypothesized that people with self-reported depressed mood were more physically frail and were also therefore more likely to have poor balance. This is supported by the higher prevalence of medication use and limitations of daily living activities also found in this study population. Physical frailty and reduced strength in general would also lead to slowed simple reaction time and balance (22), and previous research has shown that depression is associated with poorer physical performance (35).

Although the use of prescription psychoactive medications was related to self-reported depressed mood and CSRT, it could not be included in the model due to the low correlation coefficients (this was also the case when the subclass of antidepressants was included in the model alone). There was a positive relationship between self-reported depressed mood and prescription of psychoactive medications, which suggests that even with pharmacological intervention for depressed mood, people still reported symptoms of depression. In any case, the lack of strong path coefficients suggests that the psychoactive medications did not lead to significant impairments in strength, balance, or CSRT. In line with our conceptual model relating to functional performance outlined in the introduction, we did not include factors such as total number of medications or specific medical conditions as the effects of such factors would be manifest in the cognitive and physiological measures. However, additional analyses (data not shown) showed that inclusion of these variables in more complex models did not explain significantly more variance in CSRT.

We anticipated that exercise would be an important mediator on the physiological path linking depressed mood and CSRT. This was not supported, even though exercise was significantly correlated to self-reported depressed mood, quadriceps strength, and CSRT. One explanation for this finding may be that our physical activity questionnaire only assessed exercise and was therefore an inaccurate reflection of their overall activity level.

A major strength of this article is the use of path analysis modeling in a large sample. This analysis uncovered important mediating factors between depression and impaired stepping performance. This would not be evident if regression techniques were used which treat independent variables similarly, without ordering their effects in "causal" sequences. The use of CSRT also has an advantage over using falls as the outcome measure as CSRT is continuously scored and therefore provides greater scope for explaining variance in the total model. Our final model explained 37% of the variance in CSRT, whereas a previous path which aimed to explain the interrelationships among physical, cognitive, medical, or medication risk factors falls explained only 11% of the variance of retrospective falls (36).

We acknowledge that in terms of being able to generalize to the broader constructs of depression and falls, there are some limitations to the current study. We chose to use self-reported depressive symptoms rather than a diagnosis of major depression. There is evidence to suggest that depression is underdiagnosed and undertreated in older people especially given the high rates of nonmajor depression (37). Outcome studies have shown that perceived health rather than actual medical conditions is a more important factor in terms of predicting depressive symptoms and poor functional and physical outcomes. It can therefore be argued that measuring participants' perception of their own mood is acceptable (2,5). We also acknowledge that a more comprehensive

neuropsychological assessment may improve the model and that depression, falls and functional abilities are interrelated, and the cross-sectional design of the study prevents us from drawing firm conclusions about causal relationships between variables.

The findings suggest that an intervention for reducing falls in people with depressed mood may be implemented at one or several points on the model. Depression may be addressed directly through psychotherapy or careful medication management. Exercise programs have also been shown to reduce levels of depressed mood (38,39), improve cognitive abilities (39), and improve sleep quality (40) in older people and thus may reduce falls by these mechanisms in addition to improving strength and balance.

In conclusion, the results of this study show that self-reported depressed mood is related to slowed performance on a CSRT task and that this relationship is explained by underlying physiological and cognitive impairments.

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